Drowning and Near Drowning

Drowning is the third leading cause of unintentional injury death worldwide, accounting for 7% of all injury-related deaths. There are an estimated 372,000 annual drowning deaths worldwide. Children, males and individuals with increased access to water are most at risk of drowning. [1]

Definitions
Drowning is the process of experiencing respiratory impairment from submersion/immersion in liquid. Drowning outcomes should be classified as: death, morbidity, and no morbidity. Following a WHO report there is also consensus that the terms wet, dry, active, passive, silent, and secondary drowning should no longer be used [1].

Pathophysiology
After an initial gasp, with possible aspiration, or a period of breath holding, apnoea eventually exceeds breaking point and stimulates hyperventilation, causing aspiration and a variable degree of laryngospasm. This leads to hypoxia and resultant acidosis with the patient eventually losing consciousness and developing cardiac arrest. In 85% of cases, asphyxia leads to relaxation of the airway before inspiratory efforts have ceased, and the lungs fill with water. In young children, sudden immersion in cold water (<10°C) can stimulate the protective diving reflex and produce apnoea, bradycardia and preferential shunting of blood to the coronary and cerebral circulation, which may improve the victim's chances of survival.

Pulmonary oedema is a common insult. Surfactant loss occurs, producing areas of atelectasis and exudate can flood the alveoli. Further fluid shifts into the alveoli as pulmonary vessels constrict in response to the hypoxia and intravascular pressures rise. This may take minutes to days to develop but results in marked V/Q mismatching. In addition, foreign body aspiration, laryngospasm or bronchospsam may worsen the hypoxia.

Hypothermia, if it occurs, leads to a slowing of the metabolic rate but respiration is slowed even more so and hypoxia and hypercapnia develop. [2] Prolonged hypoxia can lead to CNS and renal damage. Cold water immersion may also cause life-threatening cardiac arrhythmias. [3]

In addition, haemolysis occasionally occurs after freshwater drowning. Freshwater drowning can be much faster than saltwater drowning. Salt water has a higher osmolarity than plasma and tends to draw water out of the erythrocytes. Fresh water is hypotonic; water is drawn into erythrocytes that swell and burst releasing potassium. This induces hyperkalaemia that can stop the heart. Experimentally observed differences between freshwater and saltwater drowning are unimportant in terms of management.

Epidemiology
Worldwide, drowning is the fourth most common injury after road traffic accidents, self-inflicted injuries and violence. It is more common than war deaths. It is the second or third most common cause of accidental death in children in the UK, Australia and the USA. Incidence peaks for toddlers and teenage boys. The latter are the risk-taking group. It is also a common form of suicide. [4]

Risk factors
These depend on age. In children under one year, unattended buckets of water and the bath account for most cases of drowning. Between 1 and 5 years, unattended swimming pools account for most cases of drowning. [5]

Alcohol use, water sports and unsupervised swimming, particularly in open water, are risk factors in adults. Other risk factors include epilepsy, underlying cardiac dysrhythmias, hyperventilation, hypoglycaemia, hypothermia and illicit drug use. [6]

In very cold water, hypothermia is a very potent aggravating factor that will rapidly inhibit the ability to swim. If a person falls into water at about 4°C, as in the North Sea in winter or the Arctic Ocean, rescuers have approximately four minutes to rescue the person from drowning. Cold can be a significant contributory factor to deaths in water, even with the temperature well above 4°C. [7]

In general terms, water below 15°C is more likely to be associated with hypothermia. However, other factors such as age, body fat and activity will affect the speed at which hypothermia develops.

Immediate action
- Start Basic Life Support at the scene.
- Remember, the cervical spine may be injured.
In-water resuscitation is associated with a delay of the rescue procedure and a relevant aspiration of water by the victim. In-water resuscitation appears to be possible when performed over a short distance by well-trained professionals. Reduction of submersions and aspiration when in-water resuscitation is performed is essential. In-water resuscitation by laypersons is exhausting, time-consuming and inefficient.\[8\]

**History**

Note the following:

- Mechanism and duration of submersion.
- Type and temperature of water.
- Time to institution of CPR.
- Time to first spontaneous breath.
- Time to return of spontaneous cardiac output.
- Vomiting.
- Likelihood of associated trauma, other precipitants (arrhythmia, myocardial infarction, seizure, non-accidental injury, etc).

**Examination**

- Temperature, pulse oximetry.
- Cardiac rhythm.
- Respiratory pattern.
- Look for evidence of pulmonary oedema.
- Head or neck injuries.
- Intra-abdominal and thoracic injuries are also possible (if water entered from a height).\[9\]
- Neurological status.

**Investigations**

- **ECG**: note rate, rhythm, evidence of ischaemia, J waves of hypothermia.
- **Bloods**: ABG, electrolytes, renal function, glucose, osmolarity, alcohol level, FBC, LFTs, coagulation screen, blood cultures.\[9\]
- **Radiology**: CXR, also C-spine and possibly head CT scan if indicated.

**Treatment**

This will involve several important modalities of treatment.\[9\]

- Instigate or continue resuscitation as required. Intubate if unconscious.\[9\]
- Oxygen.
- Treat hypothermia, hypoglycaemia, seizures, hypovolaemia and hypotension, if they occur.
- If the patient is awake and alert, observe for at least six hours. Pulmonary oedema may develop late (it usually develops within four hours).\[9\]
- Otherwise, the following may be needed: continuous positive airway pressure (CPAP), intubation and mechanical ventilation with high positive end expiratory pressure (PEEP), or even extracorporeal membrane oxygenation (ECMO) for severe pulmonary oedema. Rewarming by extracorporeal circulation provides efficient rewarming and full circulatory support.\[10\]
- Nasogastric tube +/- urinary catheter.
- Artificial surfactant, hyperbaric oxygen and inhaled nitrous oxide therapies are all of unproven value.
- Dialysis for acute kidney injury.
- Prophylactic antibiotics are unproven. They should be given if fever develops or there is grossly contaminated aspirated water, then targeted towards the likely pathogens. Pneumonia can be a major problem and even a fatal complication and atypical organisms are an important consideration.\[9\]

Do not be too eager to abandon resuscitation as hopeless, especially with co-existent hypothermia. Even very profound hypothermia with asystole can be treated by cardiopulmonary bypass.\[11\] Children, especially, can have remarkably good recovery after prolonged resuscitation, with no neurological problems; however, the outcome is variable. It is not possible to predict at an early stage who will have good outcome and so aggressive resuscitation should be given to all.\[12\]

**Clinical Editor’s notes (August 2017)**

Dr Hayley Willacy would like to draw your attention to this remarkable case report\[13\]. A 2 year old experienced cardiac arrest after cold water drowning and her MRI showed cerebral atrophy and grey and white matter loss on day 32. She was discharged home on day 35, unresponsive to all stimuli, immobile with legs drawn to her chest, and with constant squirming and head shaking. Normobaric oxygen was administered twice daily from day 56. Hyperbaric oxygen therapy (HBOT) was introduced on day 79. After HBOT, the patient demonstrated normal speech and cognition, assisted gait, with residual fine motor and temperament deficits. MRI 27 days after HBOT showed near-normalisation of ventricles and reversal of atrophy.

**Complications**
There are many possible complications:

- Cardiac (cardiac arrest, bradycardia, myocardial infarction).
- Pulmonary (pulmonary oedema, pneumonia).
- Neurological (stroke, cerebral hypoxia, cerebral oedema).
- Acute kidney injury.
- Haematological (haemolysis).
- Metabolic (hyperkalaemia, acidosis).
- Infective (pneumonia, septicaemia).

**Prognosis**

Drowning is a major source of mortality and morbidity in children worldwide. However, neurocognitive outcome of children after drowning incidents cannot be accurately predicted in the early course of treatment. The duration of submersion, the need for advanced life support at the site of the accident, the duration of cardiopulmonary resuscitation, whether spontaneous breathing and circulation are present on arrival at hospital, are important factors related to survival.\[14\]

Many have investigated and reported on outcome and possible predictors. However, no single system is comprehensive and there are pitfalls in the methodologies used.\[15, 16\]

Generally, the shorter the submersion time and the shorter the delay to CPR, the better the outcome.

- Prognosis is ultimately related directly to the duration and magnitude of hypoxia.
- The most significant impact on morbidity and mortality occurs before arrival at hospital.
- Poor survival is associated with the need for continued cardiopulmonary resuscitation efforts in hospital (35-60% die in the emergency department and 60-100% have long-term neurological sequelae).
- The neuroprotective effects of cold water drowning are poorly understood. Neuroprotective effects seem to occur only if the hypothermia occurs at the time of submersion (and if very rapid cooling occurs in water with a temperature of less than 5°C).
- Even with hypothermia, intact survival of comatose patients is still quite uncommon. However, there are some remarkable case histories where, even after over an hour of submersion and with initially no vital signs (rectal temperature 13.7°C), full recovery has been achieved.\[9\]
- In warm water immersion, those who were not doing well at 24 hours have a poor neurological outcome.

**Prevention**

Measures for the prevention of drowning include educating on water safety, installing barriers between non-intended users and water (eg, pool fencing), mitigating the consequences of submersion, personal protective equipment such as buoyancy aids, ancillary equipment such as swimming pool covers, and information and organisational factors such as safety signs and campaigns to teach children and adults to swim.\[5, 17\]

Even good swimmers should not swim alone as, if they develop cramp or have any other trouble, there is no one to raise the alarm. Rivers can be treacherous, with eddies and reeds. Alcoholic intoxication is a major risk. Those who go swimming alone after a night of drinking are at very high risk. Night time and intoxication also increase the risk of diving into shallow water, producing head or neck injuries.

Infants and small children may drown in the bath. The most significant factor is inadequate supervision. A study from Canada found that contributory factors were inadequate adult supervision (89%), co-bathing (39%), the use of infant bath seats (17%) and co-existent medical disorders predisposing the infant or child to the drowning episode (17%).\[18\]

**Further reading & references**

1. **Drowning; World Health Organization**
9. Harries M; Near Drowning (Review) BMJ 2003; 327:1336-1338

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